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Introduction to Mixed Variable Optimization (MVO)

LA-UR-

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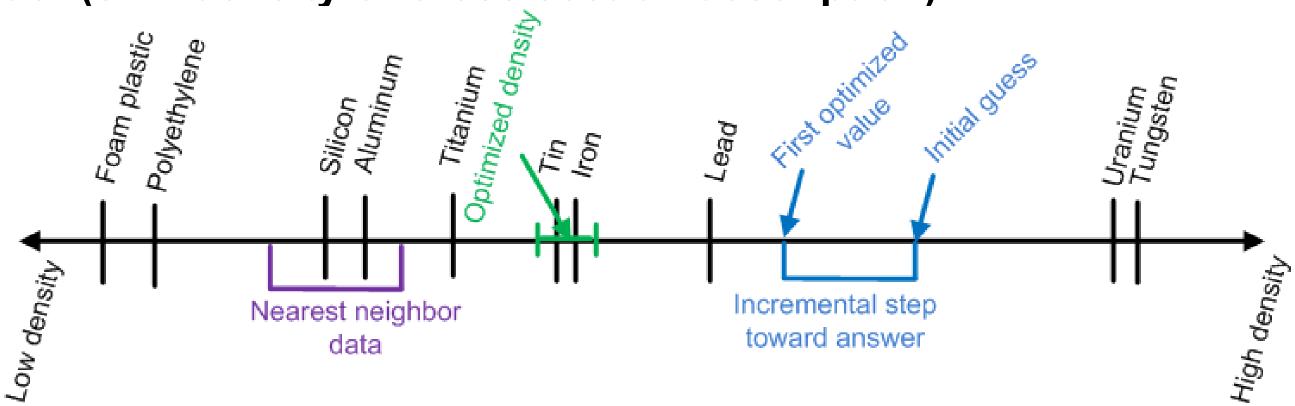
Abstract

Mixed Variable Optimization (MVO) is an optimization method that uses discrete (categorical) and continuous variables in its optimization process. This method of optimization is applicable to highly nonlinear problems where the information used in the optimization is of poor quality of has minor inaccuracies in the data sets.

Consider finding the possible material densities in a real number continuous space

- **In “standard” methods the materials that compose a layer of the unknown object must be described by a real number continuous solution space that must have order (ex. - density or cross section description)**



- **The optimization above must move along the density space parameter and must move past all materials between the initial guess and the final answer to optimize a solution**
  - **Requires good initial guesses to speed up optimization (all methods are improved by good initial guesses)**
  - **Must have a tolerance – user must select which material is best when more than one is within the uncertainty**
  - **Noise and/or uncertainty in data leads the optimization routine to the wrong answer**

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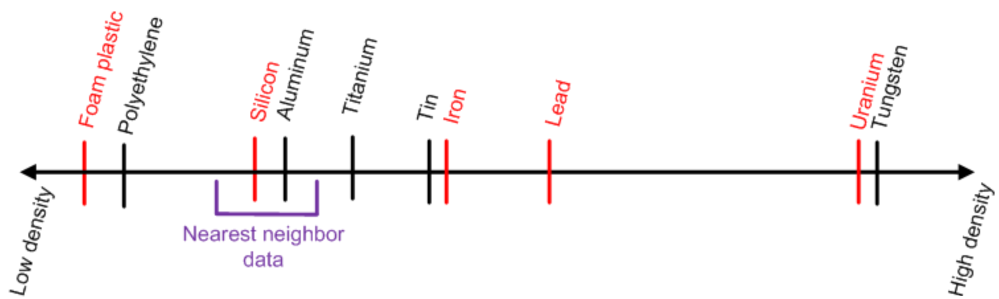
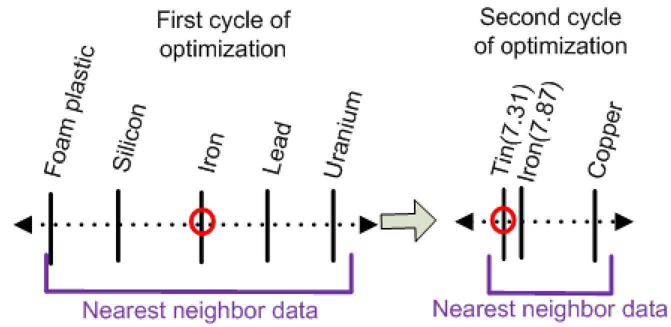
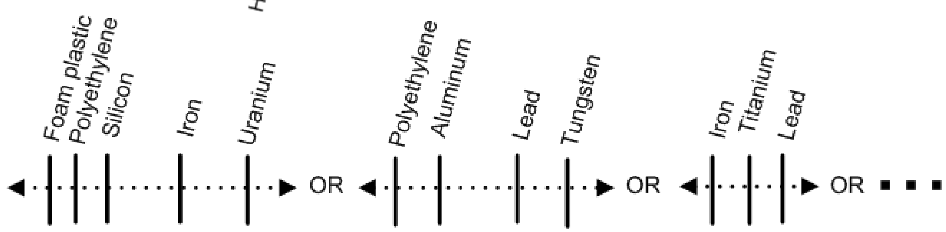
Consider finding the possible material densities in a discrete "feasible" space

- **Using a "feasible" space in the optimization limits the possible densities only to those materials considered in the forward model optimization.**





- **I can define the feasible space for materials any way I want**



- **Using a "feasible" space = discrete and continuous optimization**
  - **Limits the density space to relevant values – speeds up optimization**
  - **Makes the optimization more robust**

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MVO’s main advantages:

- **I can define my optimization problem in a more realistic manner**
  - Parts are discrete and continuous
- **I have flexibility in constraining my problem in any way I want as long as my options are defined**
- **I am optimizing the relative difference between the forward model and the data – poor data can still be analyzed (within reason)**

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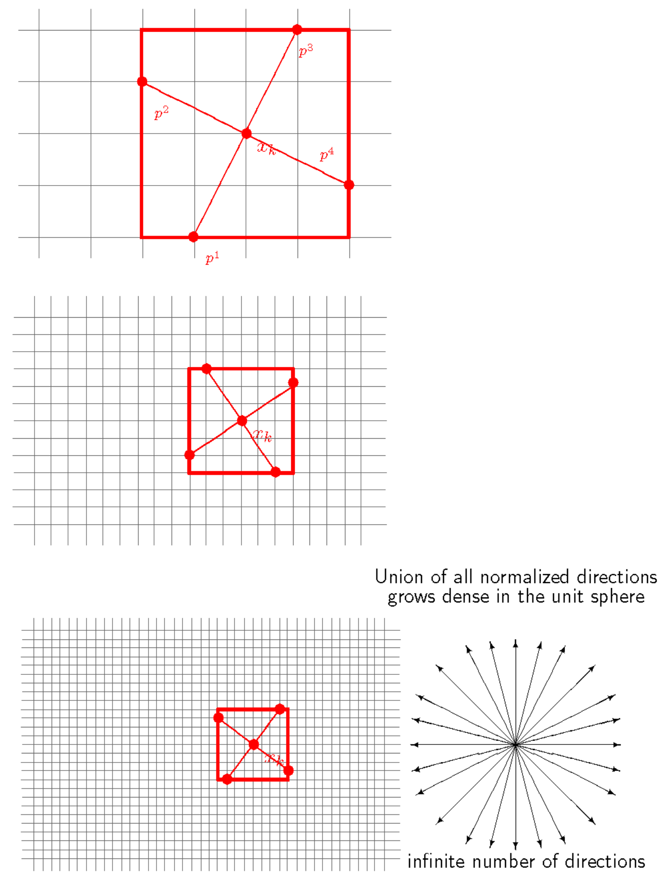
MVO uses mesh adaptive direct search algorithms

- **Method is derivative free**
- **Mesh Adaptive Direct Search algorithms**
  - Is convergent based on non-smooth analysis
  - Puts an adaptive mesh over the parameter space and searches the parameter space on the mesh
  - Uses search patterns that cover space thoroughly
- **Uses a "neighborhood rule" to determine which discrete variables can be switched in the optimization.**
- **At each iteration**
  - Generates trial points on the mesh
  - Evaluates functions at trial points
  - Adapts mesh to find local optimizer

ORTHOMADS – 2008



- ORTHOMADS is deterministic. Results are reproducible on any machine.
- At any given iteration, the directions are orthogonal.

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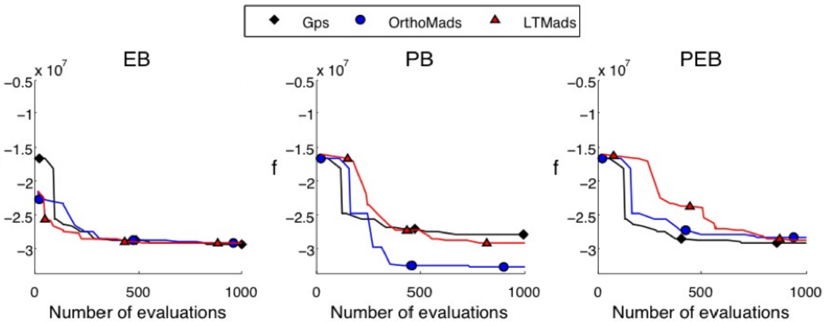
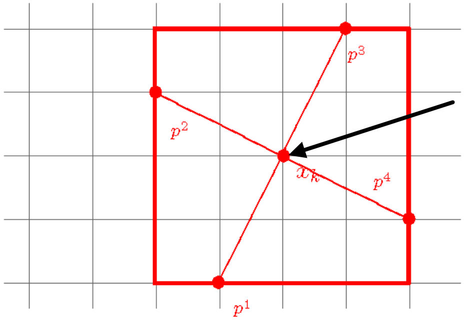
Mesh adaptive direct search algorithms(cont.)

- **Uses different barrier conditions (limits which solutions to consider)**
  - Progressive
  - Extreme
  - Progressive-to-Extreme
- **Uses different constraints**
  - Unrelaxable
  - Relaxable
  - Hidden
- **Can use surrogates to speed up optimization**
- **Different pattern search methods are combined with different barrier conditions/constraints (and surrogates) for different applications.**





Surrogates help find this search point

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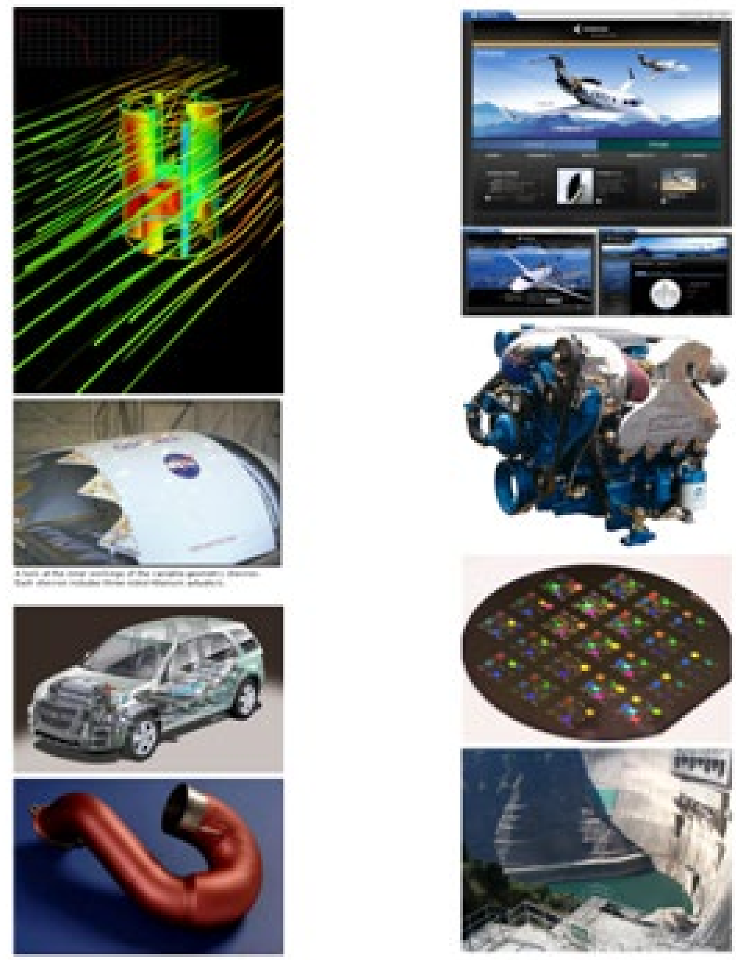
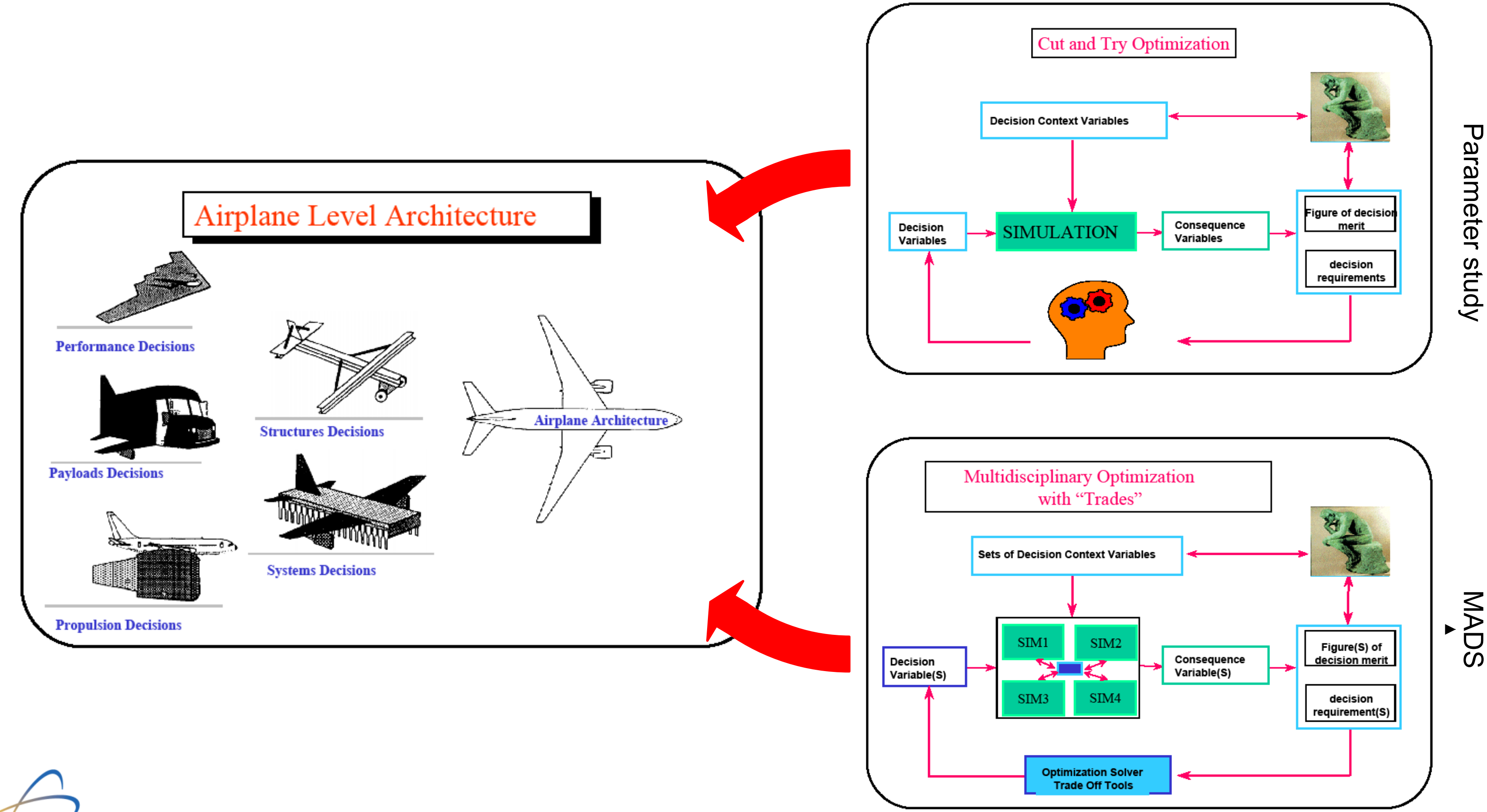
MADS used for many MVO applications

- **A few of the many companies that use MADS**
  - Boeing, Airbus, Exxon Mobil, General Motors
- **A few of the many applications solved by MADS**
  - Aero acoustic shape design
  - Fuel cell vehicle development
  - Thermal insulation design
  - Aircraft design
  - Hydraulic power train design
  - Nanostructure design
  - Structural health monitoring



Example from the Aerospace Industry (Dennis)



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